# On the use of NWP for Cloud Base Height Estimation in Cloud Camera-Based Solar Irradiance Nowcasting

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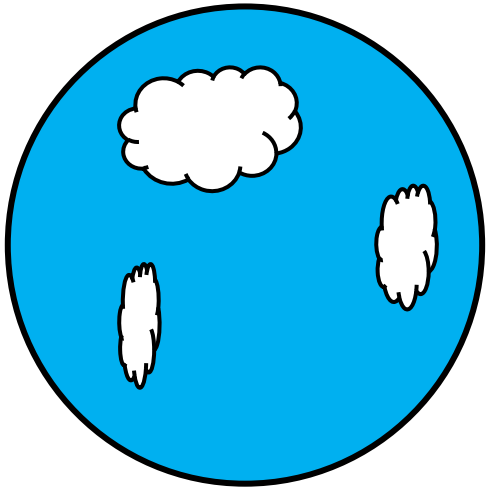
# Outline

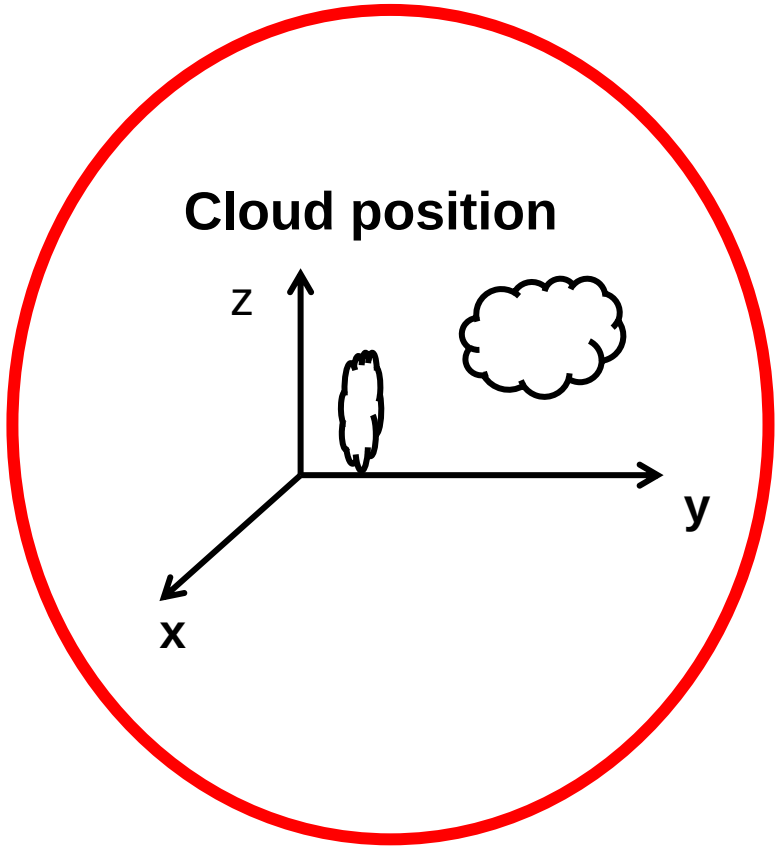
- Reminder: Cameras and cloud height for nowcasting
- Ceilometer – suitable? Needed? Cost reduction potential?
- Numerical Weather Prediction
- Examples from Plataforma Solar de Almeria (PSA), Spain
- Preliminary comparison results
- Outlook
    - Work is ongoing – discussion and feedback is appreciated

# Reminder: Cameras and cloud height for nowcasting

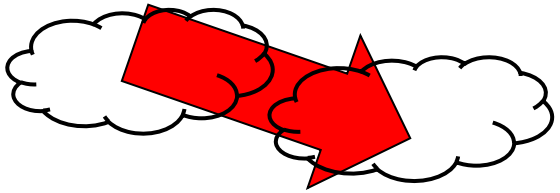
**Cloud detection**



**Cloud position**



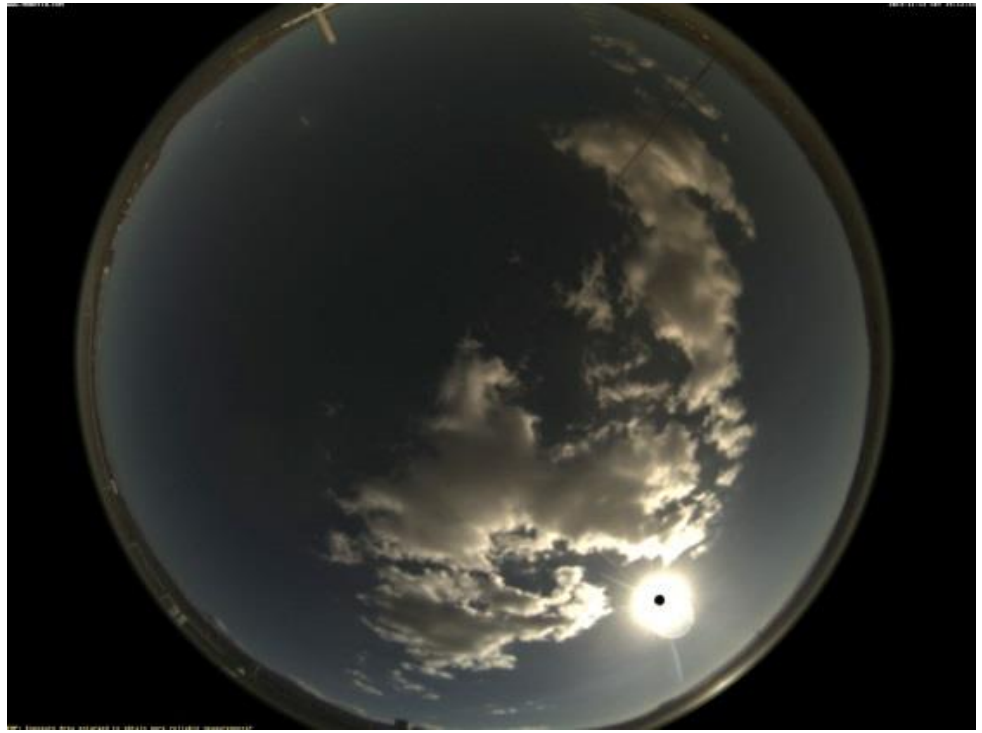

**Cloud motion**

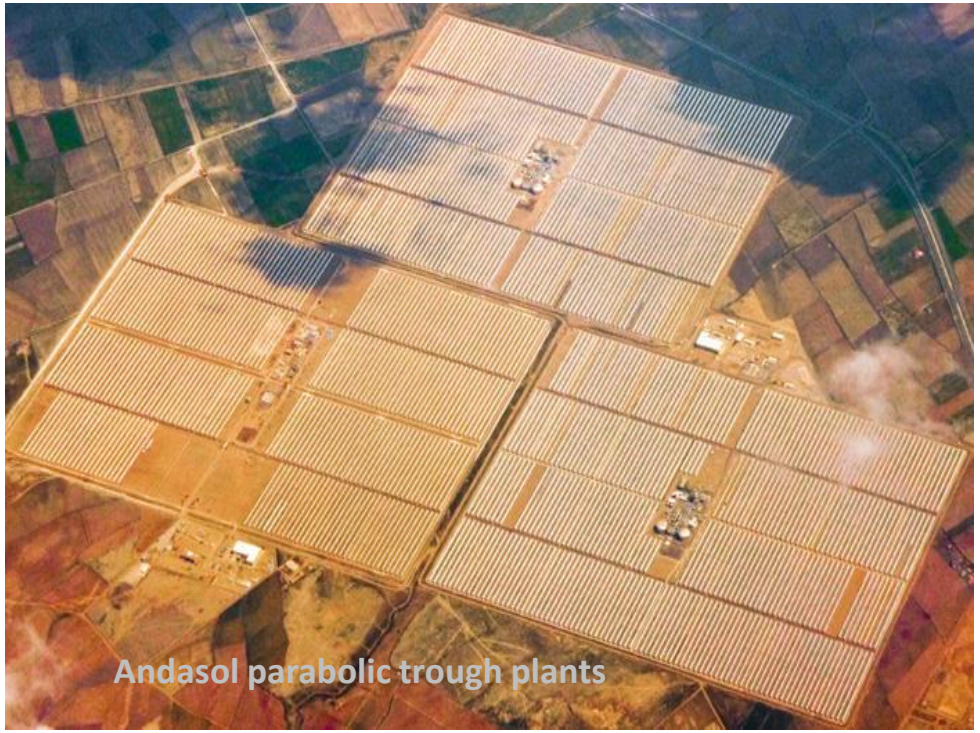


**Nowcast**

# Reminder: Cameras and cloud height for nowcasting

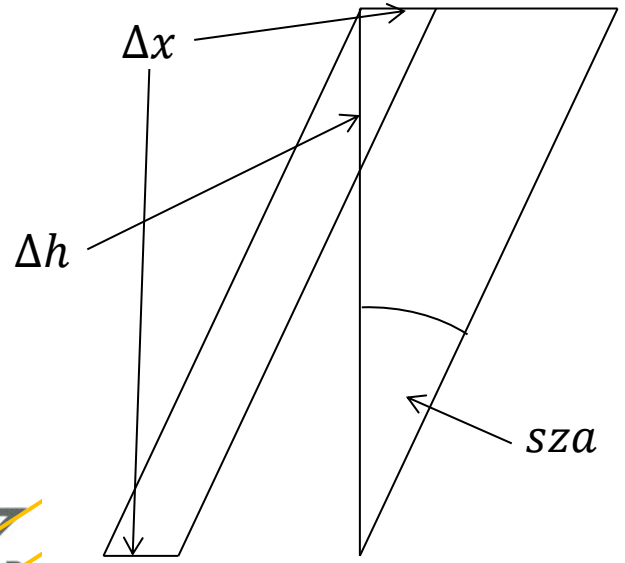
- Not all clouds detected by the camera are relevant

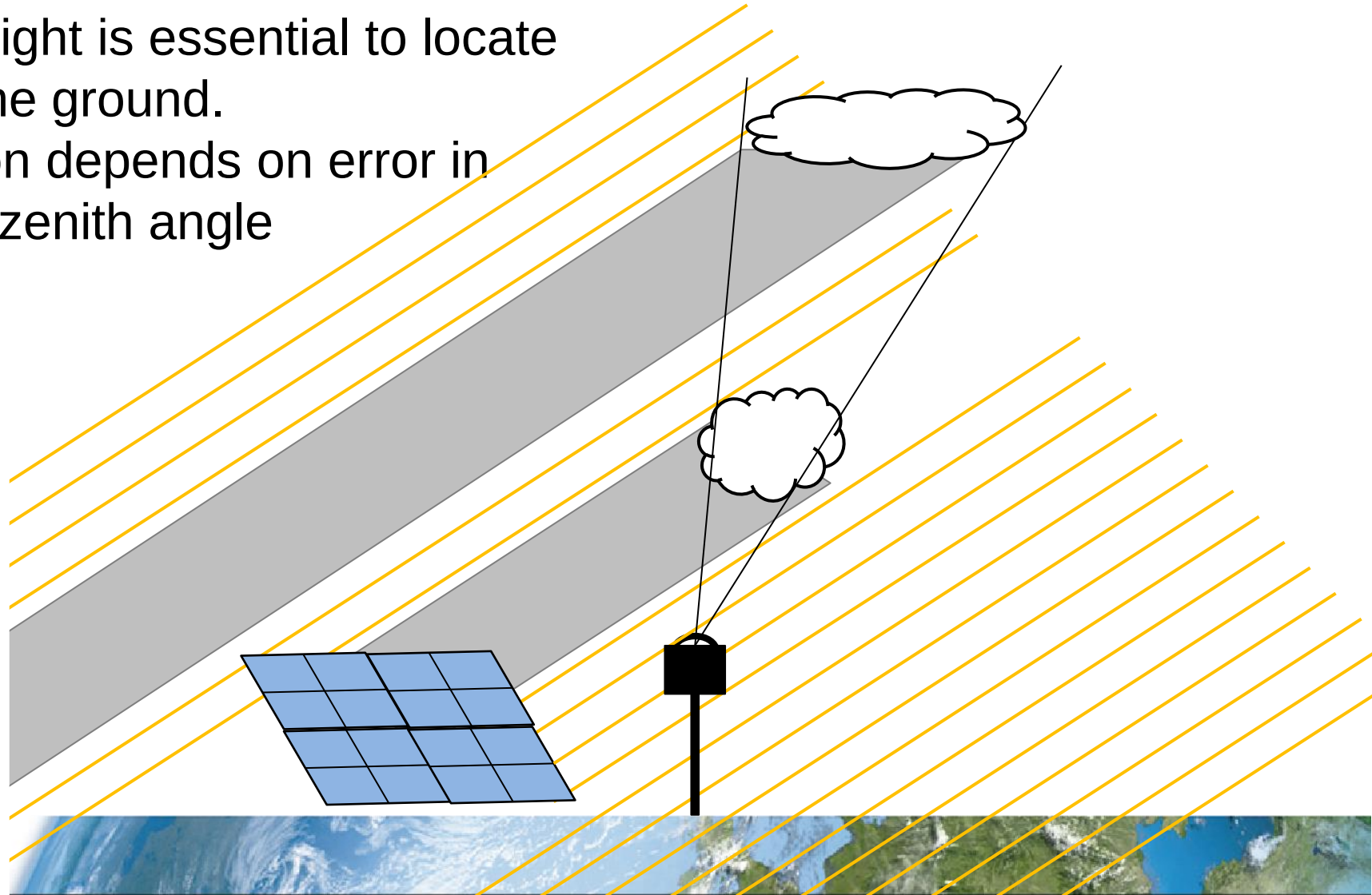




# Reminder: Cameras and cloud height for nowcasting

- Knowledge of cloud height is essential to locate the cloud shadow on the ground.
- Error in shadow location depends on error in cloud height and solar zenith angle



# Reminder: Cameras and cloud height for nowcasting

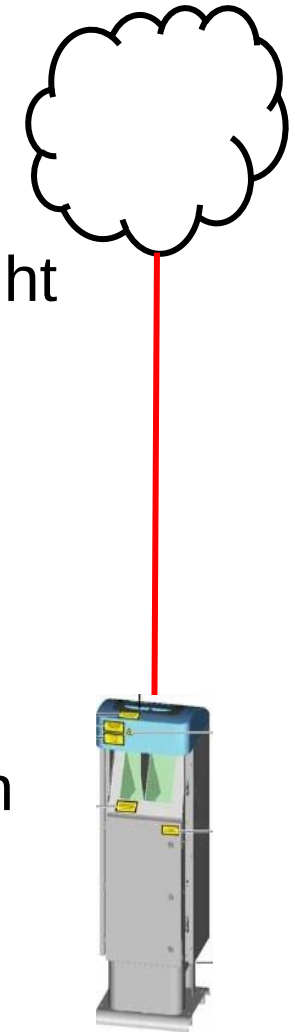
- Longest possible forecast horizon with one single cloud camera strongly depends on cloud height and wind speed

- Examples: 75° max zenith angle, 1km cloud height,
  25m/s wind speed: ~5min
  75° max zenith angle, 10km cloud height,
  30m/s wind speed: ~41min



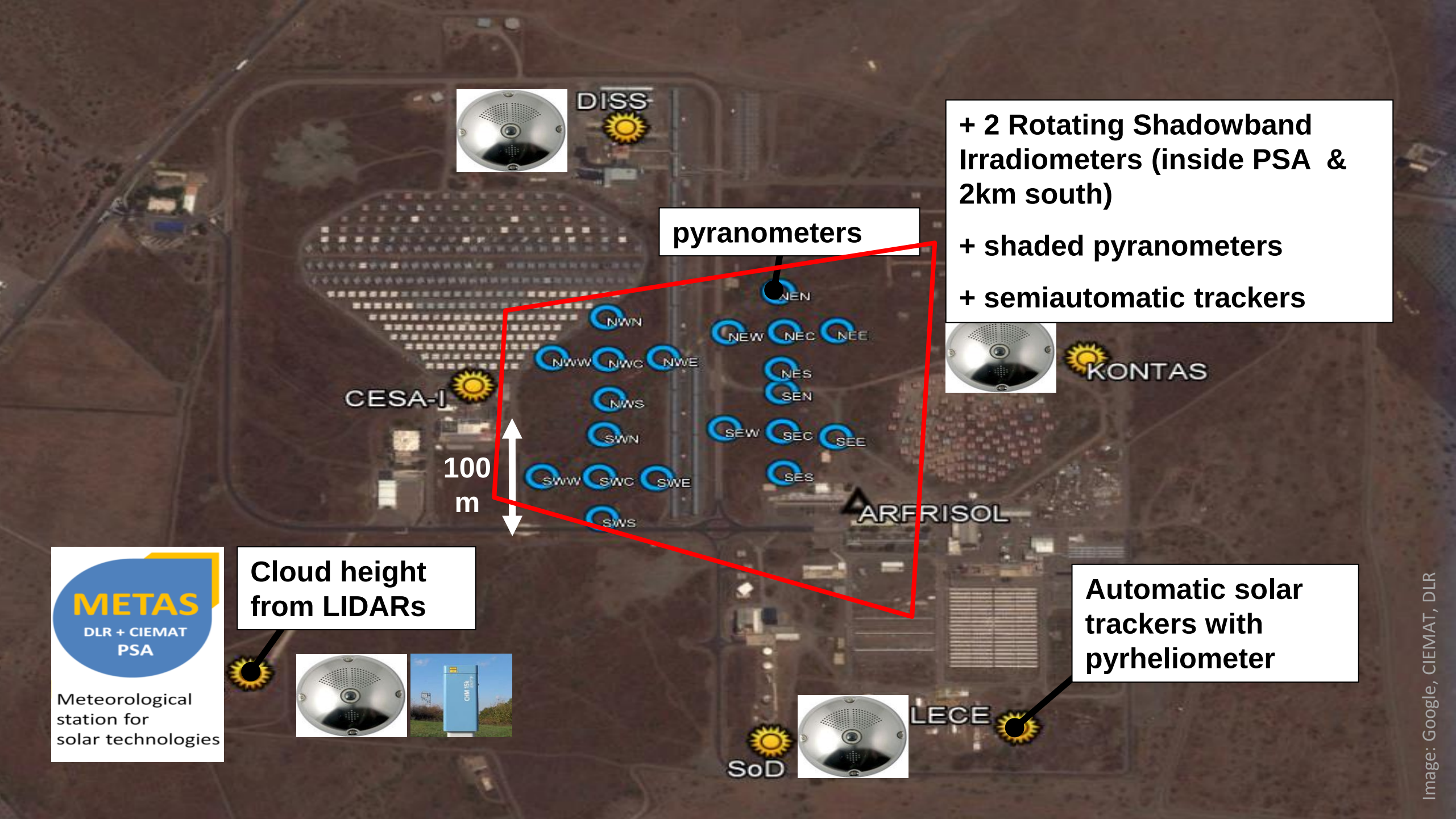
# Cloud base height from Ceilometer

- State of the art is ceilometer.
  - Measurements are taken in a vertical column above the ceilometer.
  - Time difference between sent and detected laser pulse derives the height information
  - Laser signal cannot pass through thick clouds ➔ no information above these clouds can be obtained.
  - In this talk: 1 full year of ceilometer data from Plataforma Solar de Almería (2013-11-05 until 2014-11-04)
  - This talk: Jenoptik CHM 15k ceilometer, FOV 0.45mrad, pulse repetition rate ~5khz, 1cbh value every 15s, measurement accuracy 5m.



# Plataforma Solar de Almería (PSA)


DLR

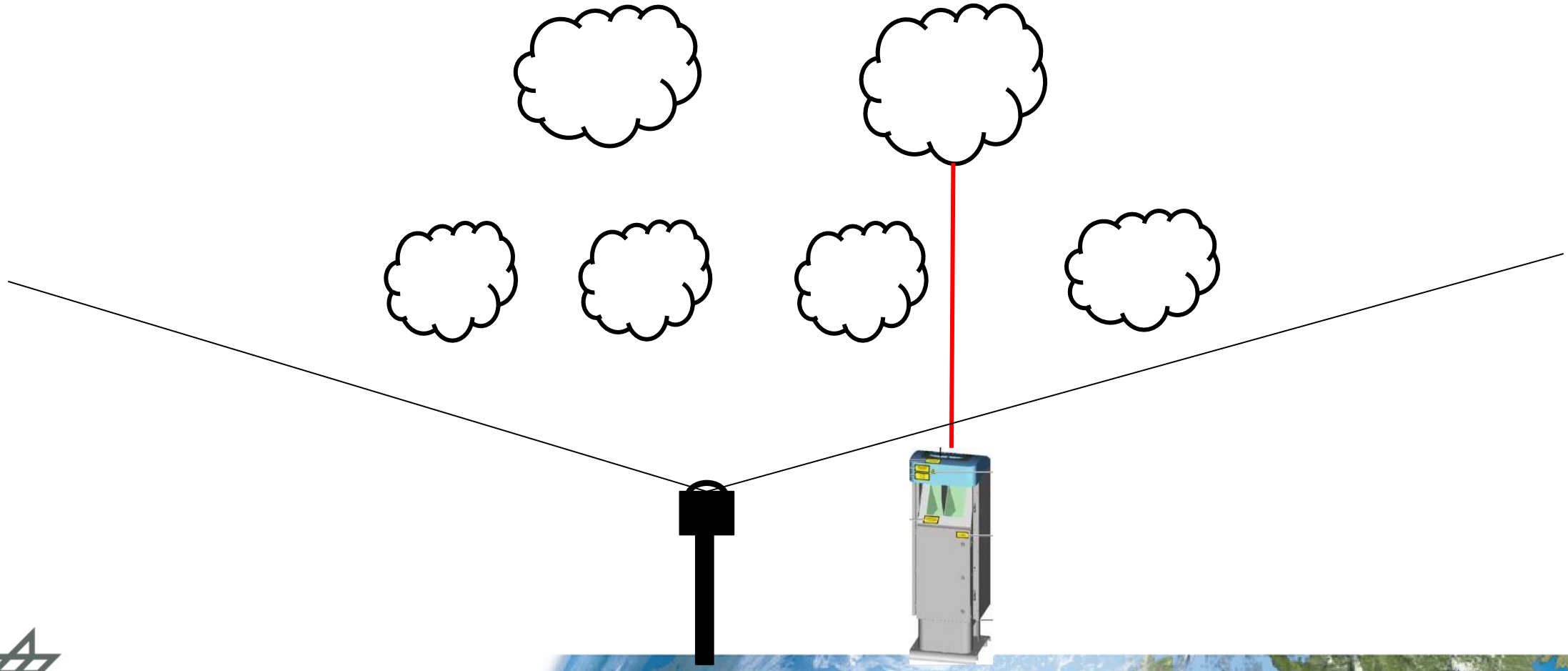

DISS
+ 2 Rotating Shadowband Irradiometers (inside PSA & 2km south)
+ shaded pyranometers
+ semiautomatic trackers
pyranometers
NEN
NWN
NEW
NEC
NEE
NWW
NWC
NWE
NES
SEN
CESA-I
NWS
SWN
SEW
SEC
SEE
100 m
SWW
SWC
SWE
SES
SWS
KONTAS
ARFRISOL
METAS
DLR + CIEMAT
PSA
Meteorological station for solar technologies
Cloud height from LIDARs
Automatic solar trackers with pyrheliometer
LECE
SoD
Image: Google, CIEMAT, DLR

# Cloud base height from NWP

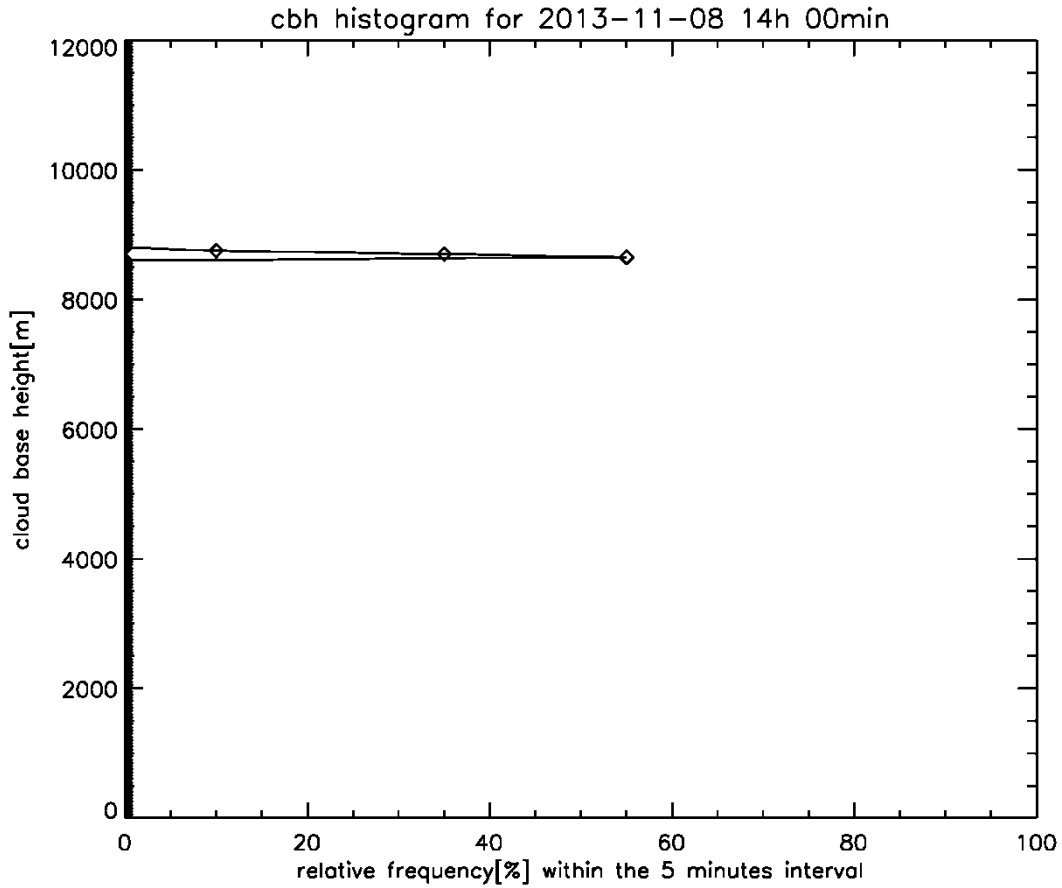
In this study:
compare ceilometer cloud base height with NWP output (ECMWF IFS forecast)

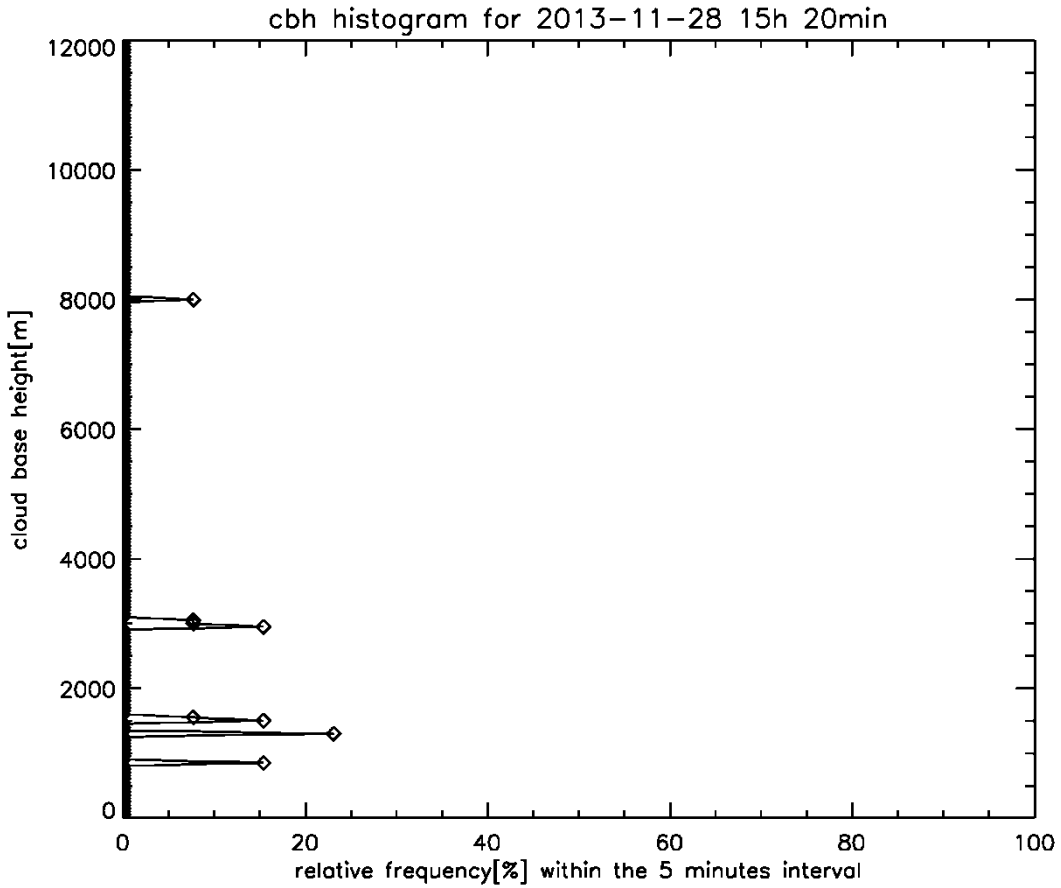
- Cloud base height is a part of IFS standard output.
- also known as cloud condensation level.
- 3h temporal resolution, scaled down to 1h resolution.
- 11km spatial resolution, 137 vertical levels.
- for each day, 0 UTC run of the same day is used in this study

# How representative is a ceilometer cbh measurement for cloud base height in camera FOV ?



# Ceilometer cbh: histograms as indicator of representativeness



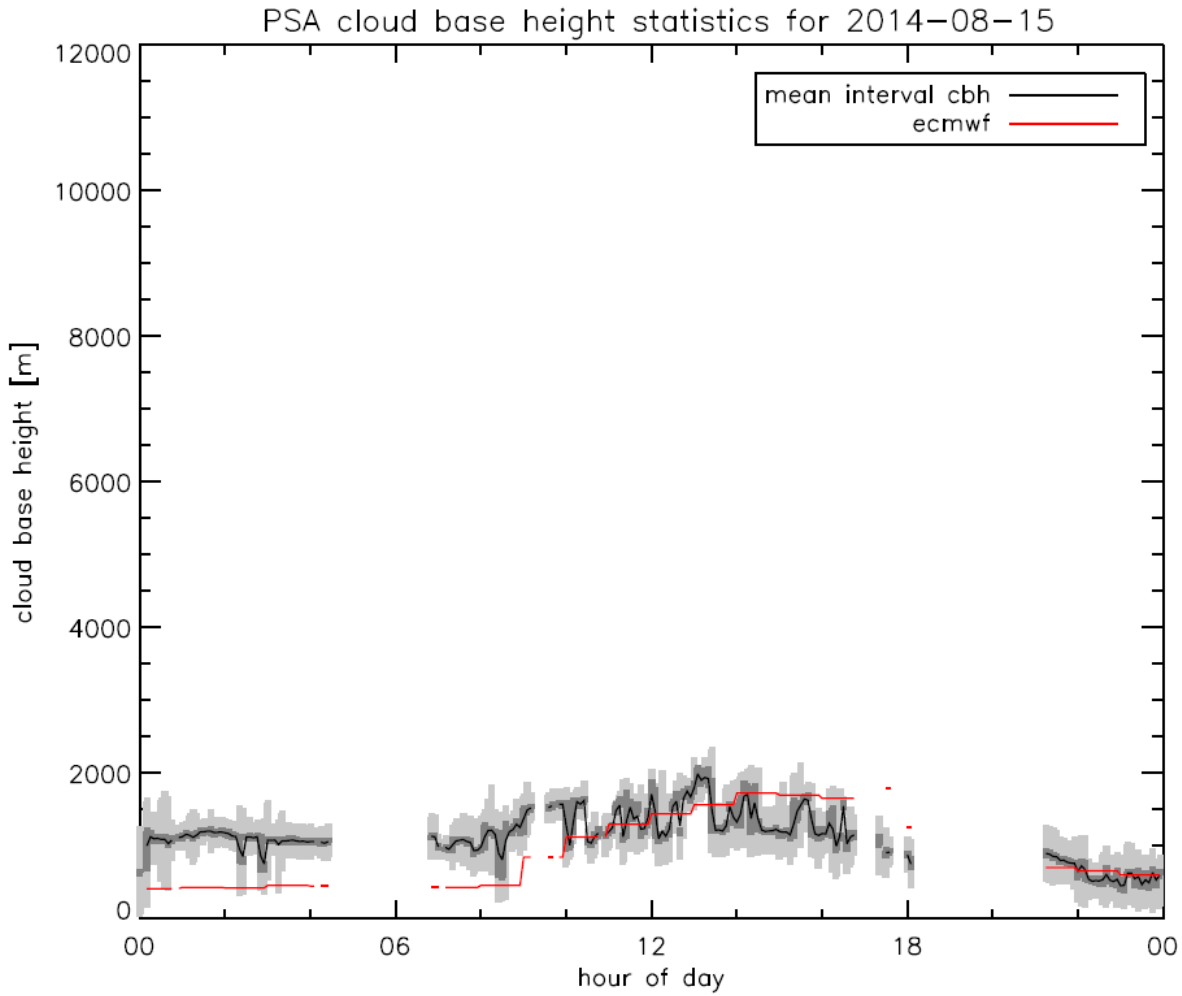




Use single value? Mean value? Median? Most frequent value?
Mean value in this study, but this issue is still not fully discussed…

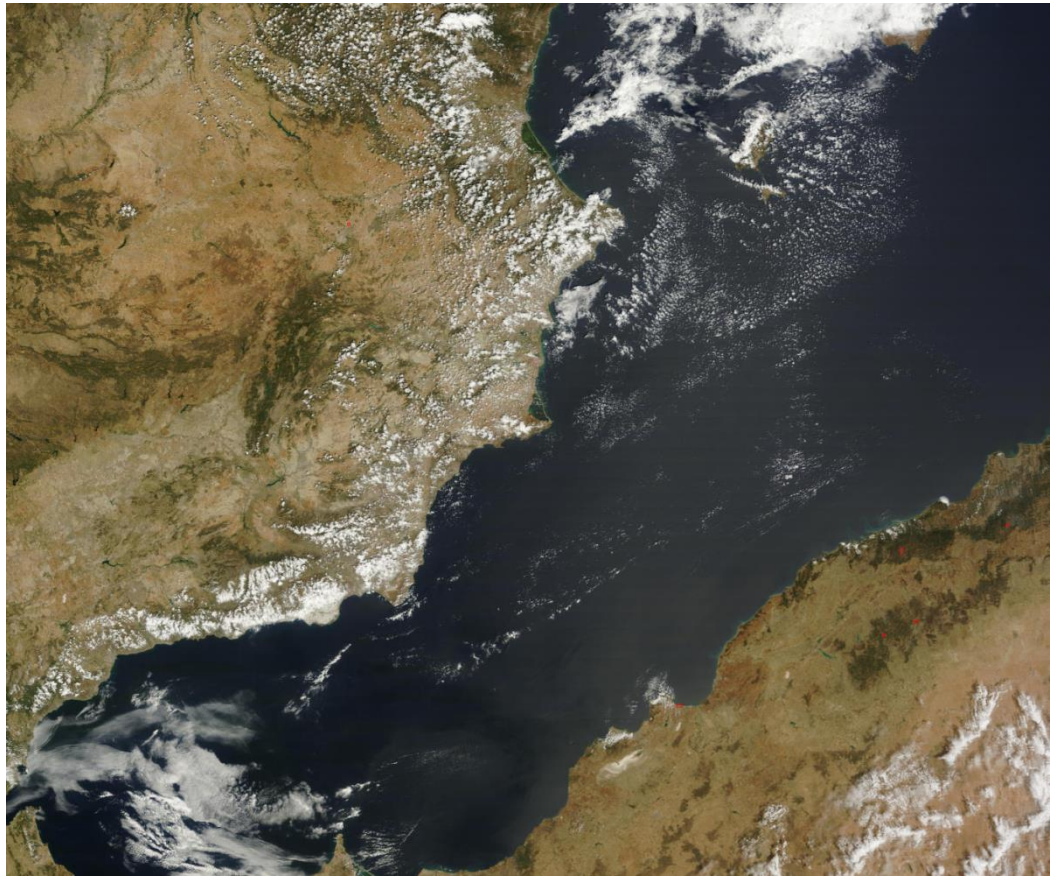
# Some example situations…

Within ceilometer 0.25/0.75 percentile interval

Within min/max interval




Terra MODIS, 2014-08-15 11:00 UTC. Source: NASA



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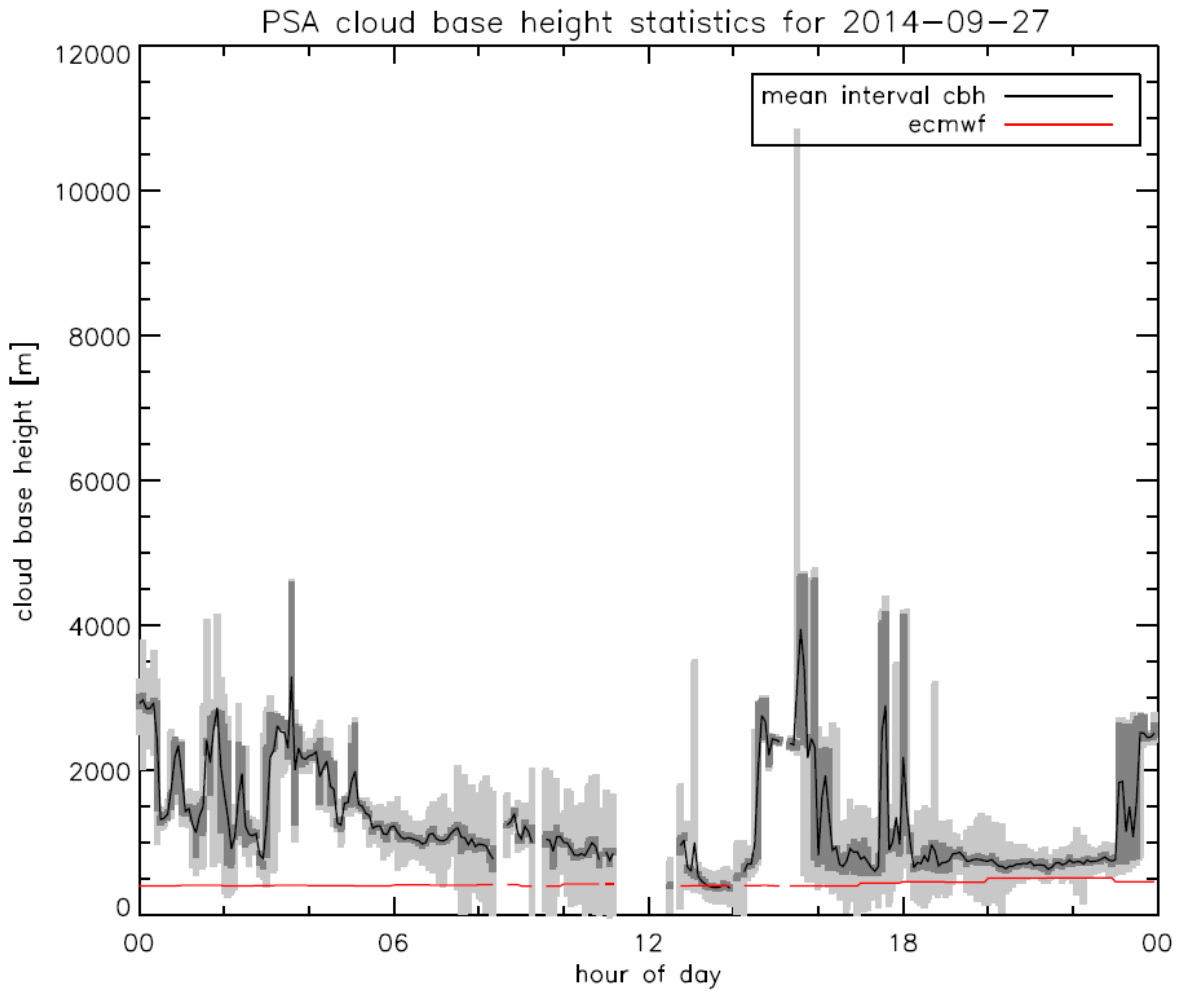
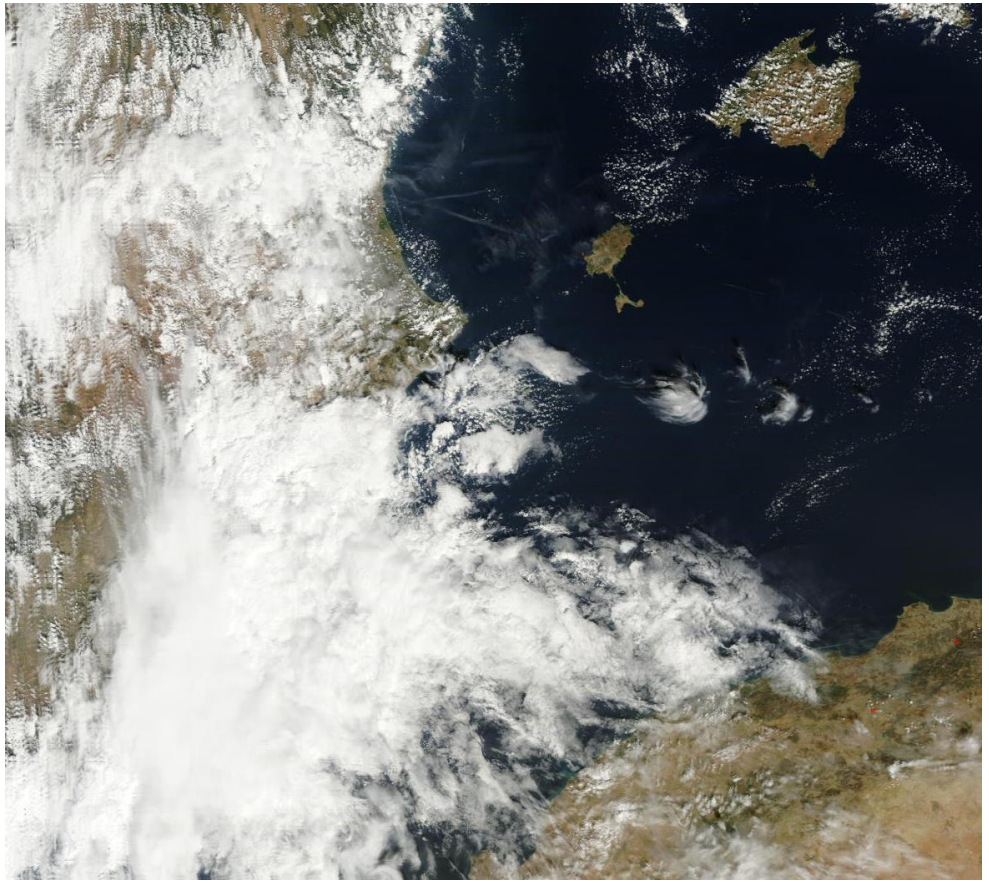



Terra MODIS, 2014-09-27 10:40 UTC. Source: NASA



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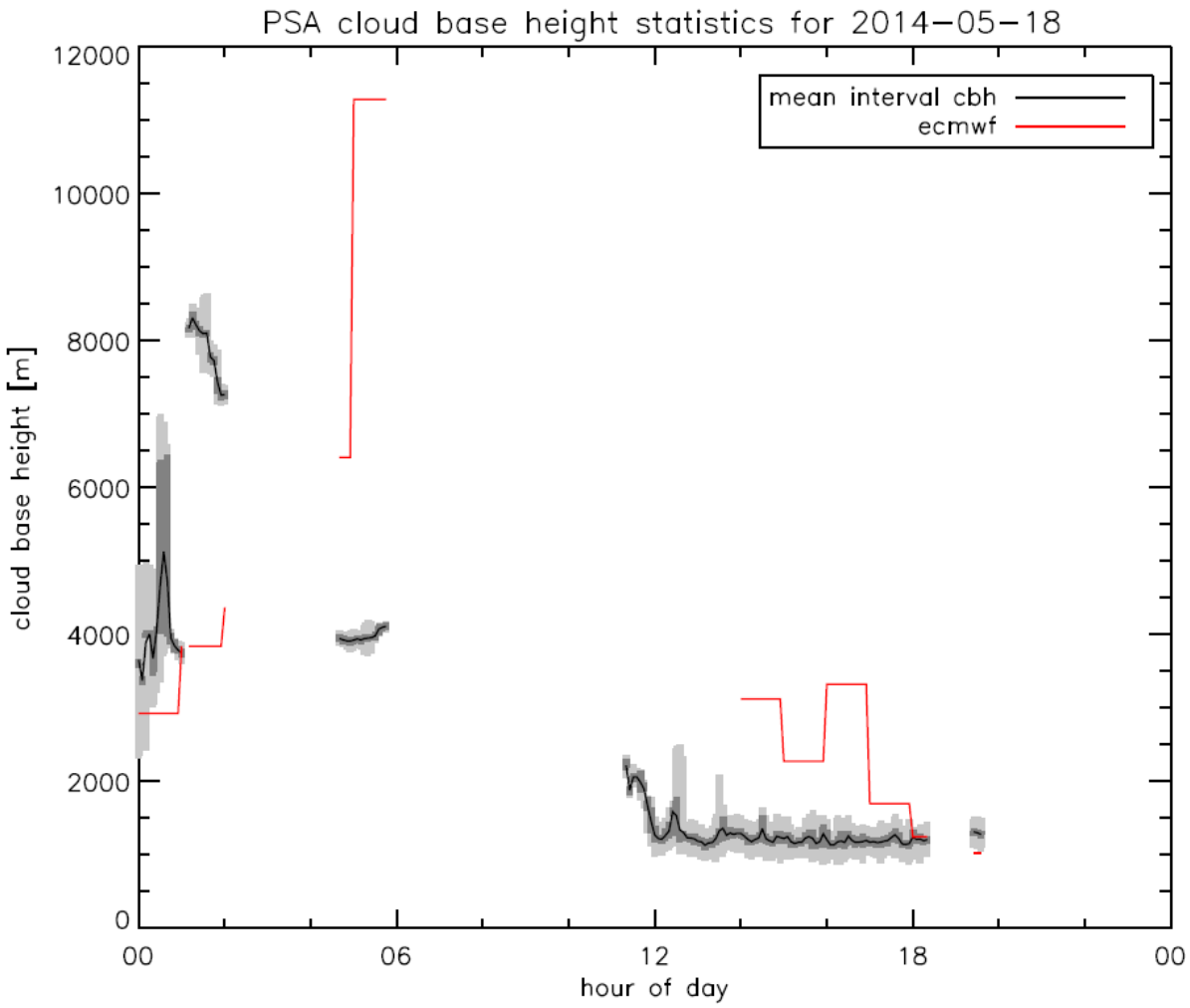
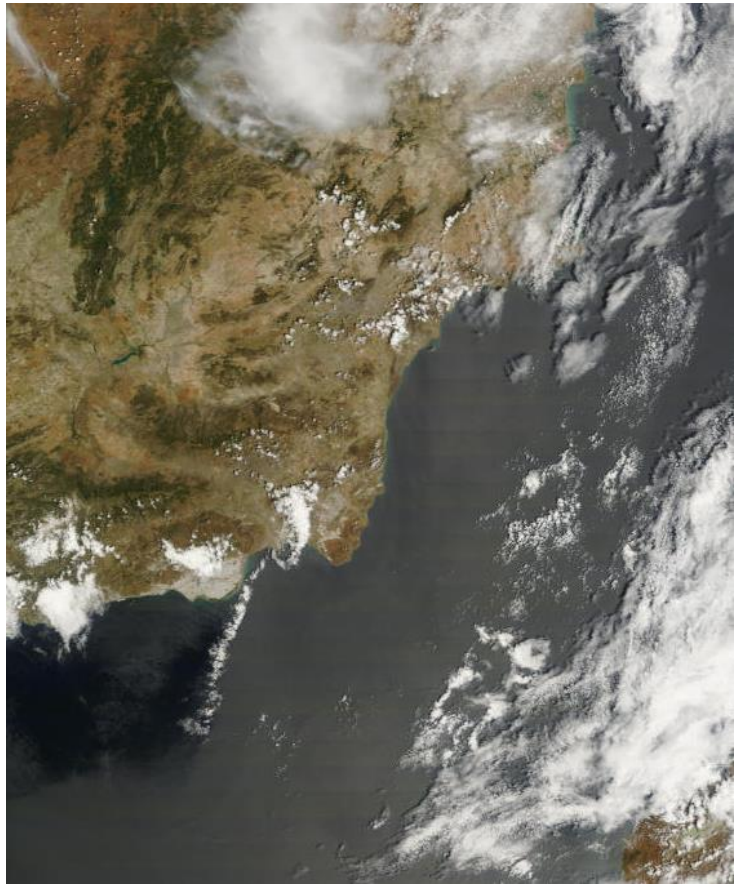


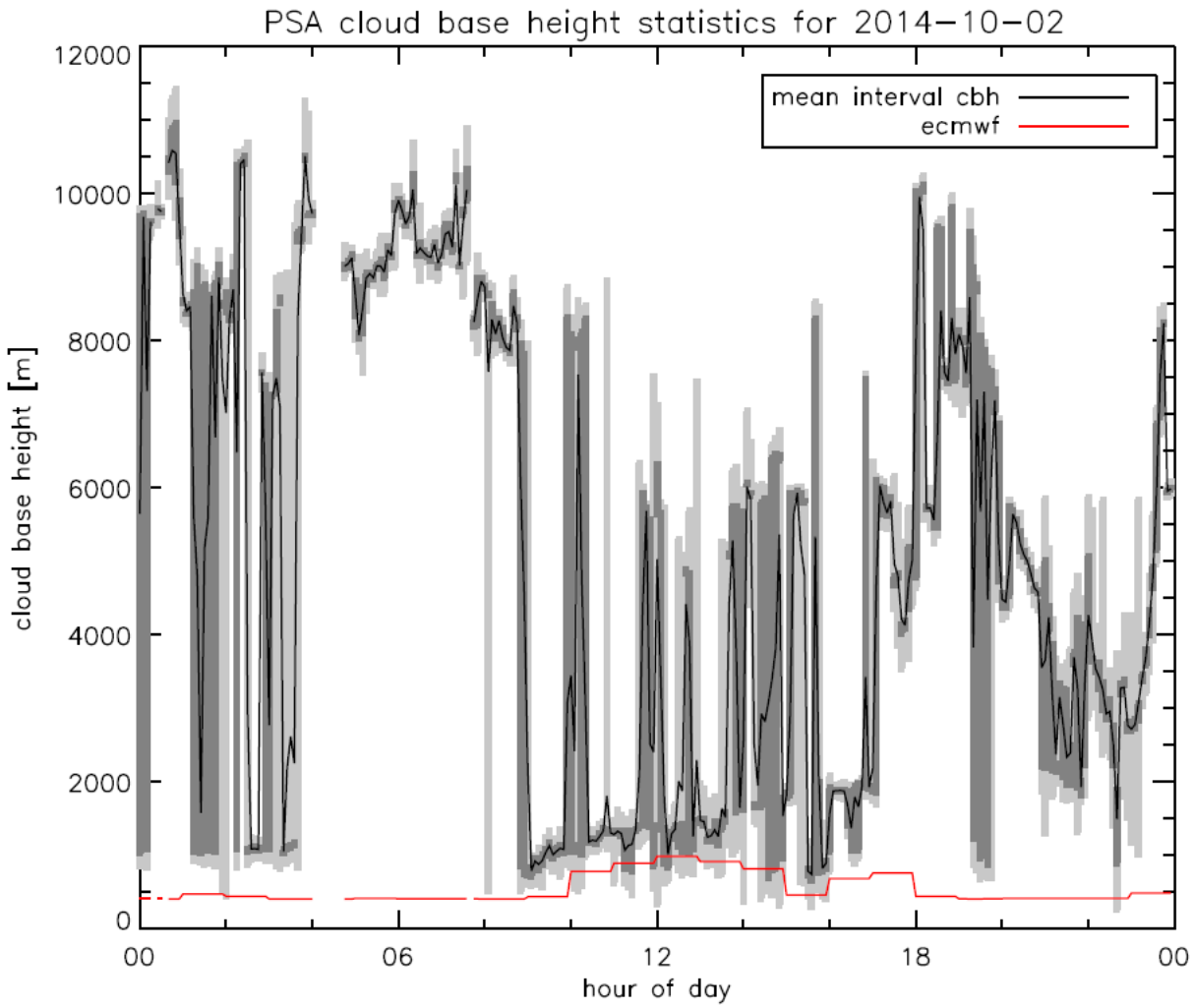

Terra MODIS, 2014-05-18 11:05 UTC. Source: NASA



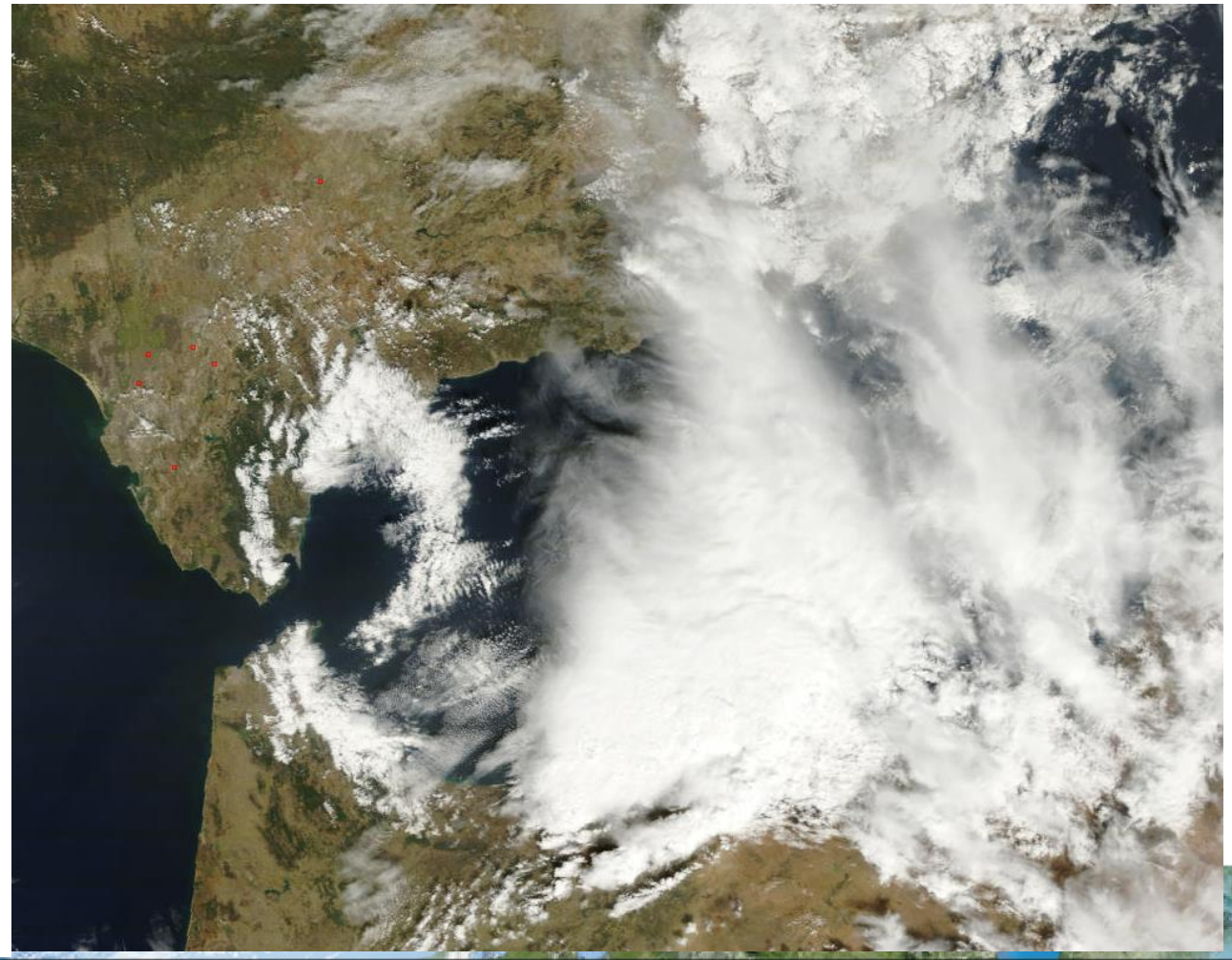
# Challenge: Broken clouds below a cirrus layer

Within ceilometer 0.25/0.75 percentile interval

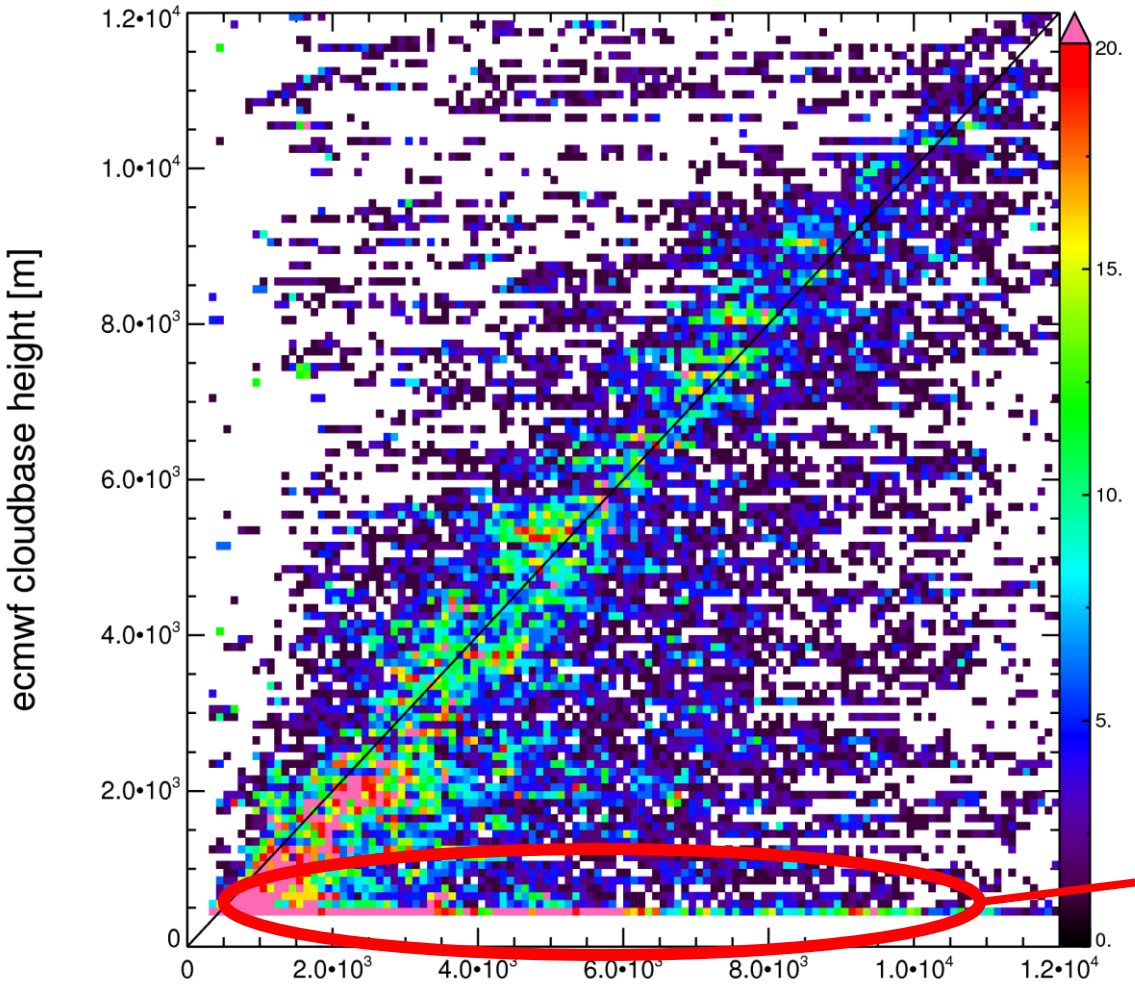
Within min/max interval




Modis/Terra, 2014-10-02 11UTC. Source: NASA



# All sky condition results

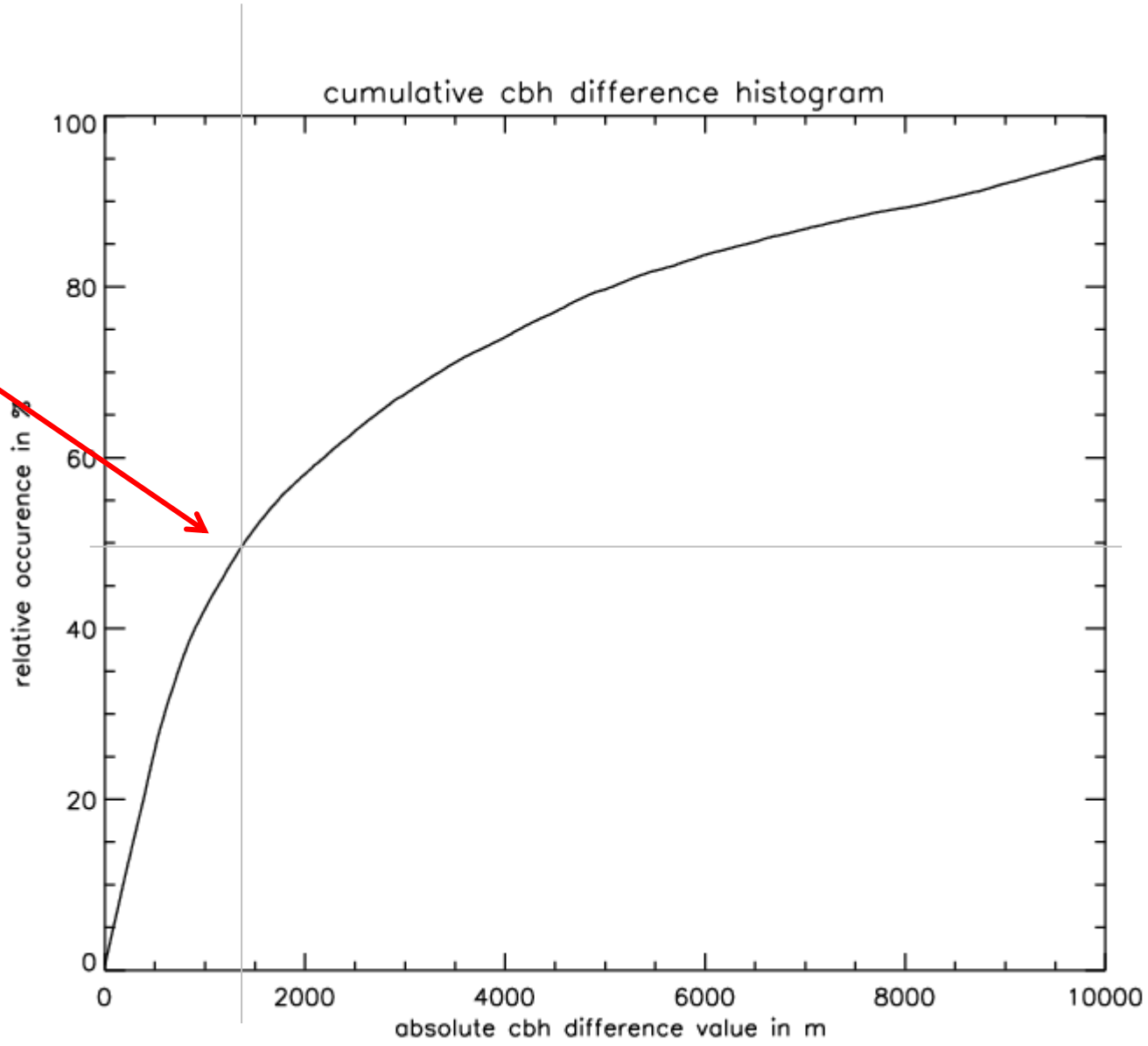



| | |
|---|---|
| N: | 41731 |
| bias: | 1092.44 |
| rmse: | 5527.28 |
| mae: | 3551.98 |
| pearson: | 0.50 |
| fit m: | 1.00 |
| fit offset: | 1076.54 |

Multilayer situation

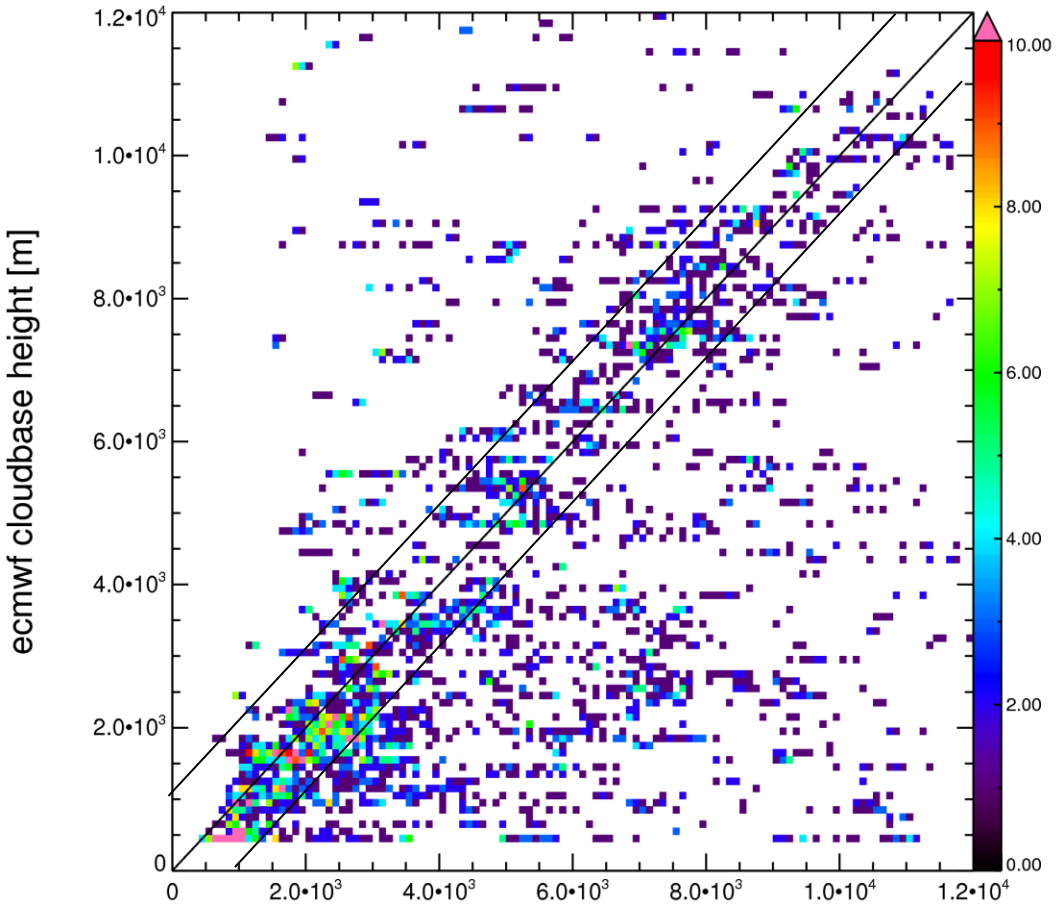
# All sky condition results

- Absolute cbh difference is below 1.5km in 50% of all cases.
- Only 4% of ecmwf cbh within ceilometer 25% to 75% percentiles.
- 18% of ecmwf cbh within ceilometer min/max interval.



# But stop – we want to track scattered cloud fields in our application the rest is not of interest…

Only cases where the satelllite detects scattered cloud conditions




| | |
|---|---|
| N: | 5285 |
| bias: | 1177.19 |
| rmse: | 5537.46 |
| mae: | 3313.12 |
| pearson: | 0.43 |
| fit m: | 0.87 |
| fit offset: | 1816.90 |

# What does 1 km difference in cloud base height means?

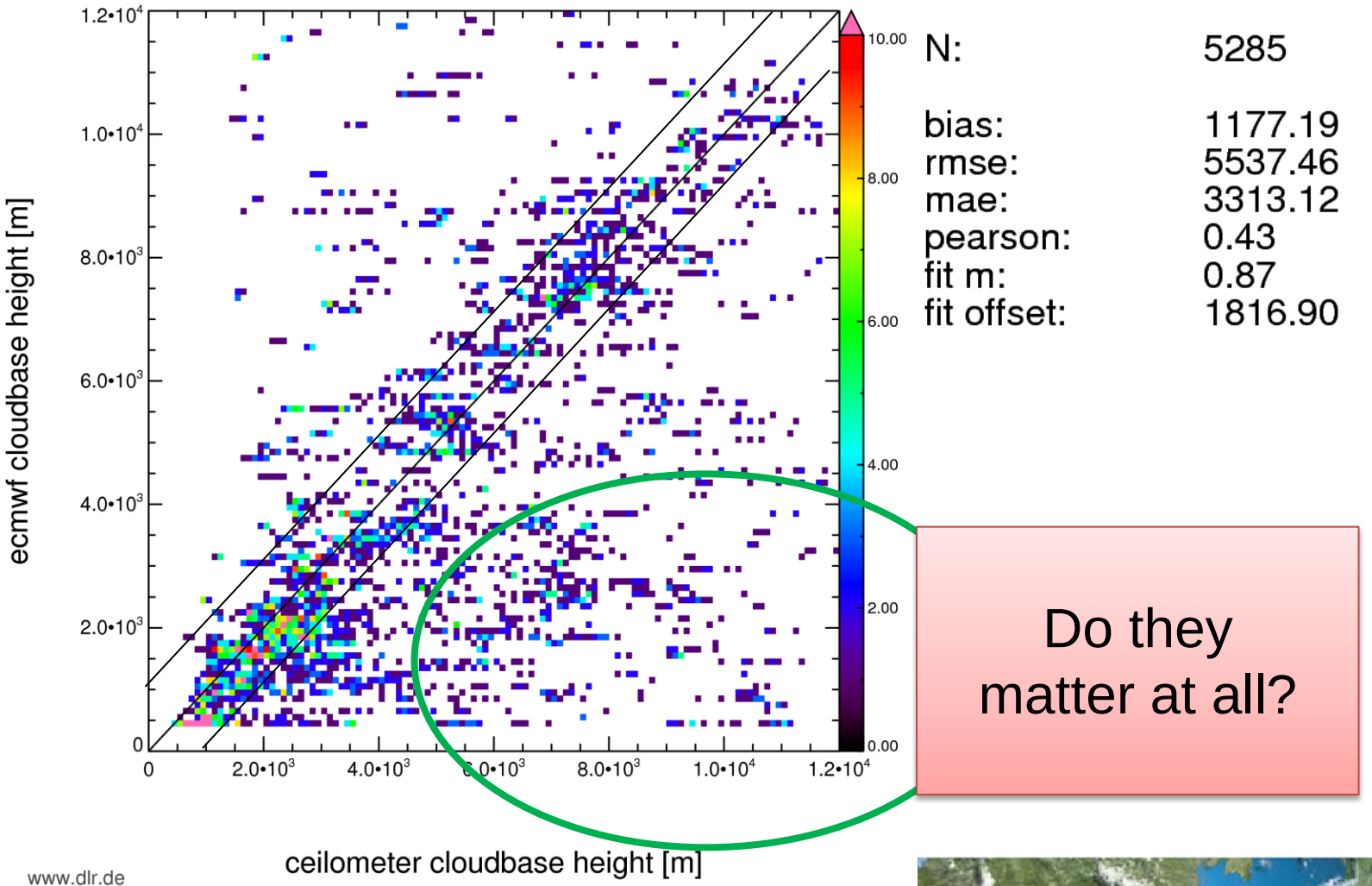
- low cloud, 25 m/s speed
  1 –> 2 km means 5 to 10 min within field of view in camera
- High cloud, 30 m/s speed
  10 –> 9 km means 41 to 37 min within field of view

- Error in shadow position strongly dependent
  on sun position
- Do evaluation of cloud masking as next step…



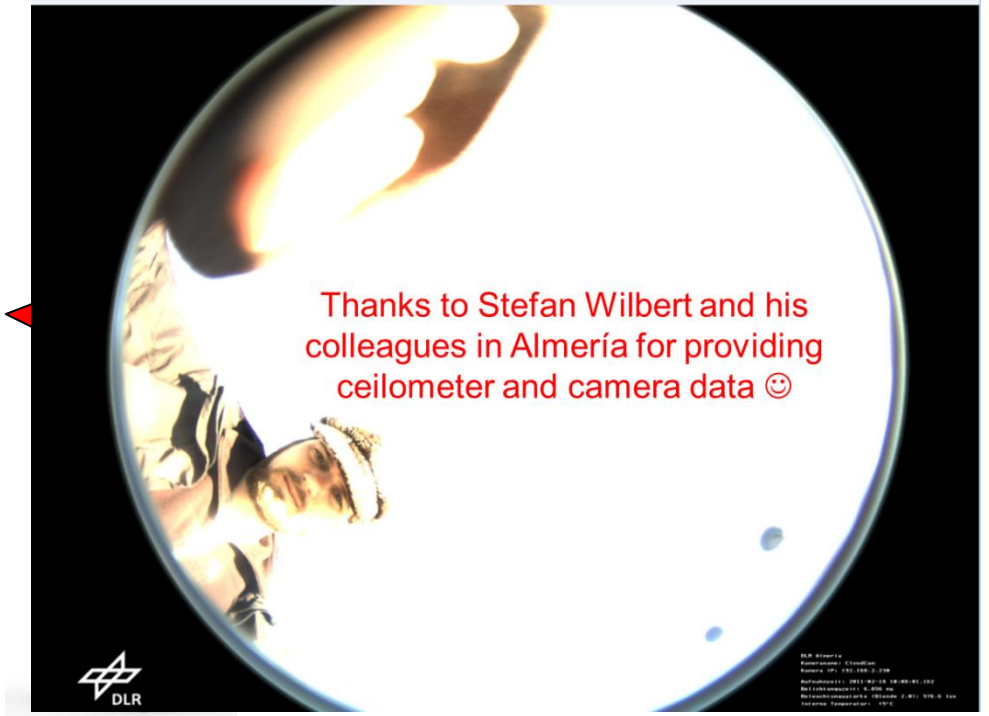
# But stop – we want to track scattered cloud fields in our application the rest is not of interest…

Only cases where the satelllite detects scattered cloud conditions




Do they matter at all?

# Conclusions




- Cloud height is very variable in time and space
  - using of ceilometer at nearest airport is a good idea only in few meteorological conditions (e.g. maritime strato-cumulus)
- Ceilometer at site – still be aware about representativity
  Which cloud to track? Variability of height inside field of view is an issue
- NWP is available anyhow at power plant site
  - Quantification vs. ceilometer in all sky conditions
  - Quantification vs. ceilometer in solar energy interesting conditions
  - Verification in nowcasting of camera cloud masks

- Check different stations
  ➔Who has ceilometer data and likes it to be checked?